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GLACIAL LAKES OF PUGET SOUND

PRELIMINARY PAPER

J. HARLEN BRETZ

On the western margin of the North American continent an uninterrupted fjord coast extends from Cross Sound in the Alaskan panhandle southward to Puget Sound in the state of Washington. The topographic expression of the whole extent of coast line is glacial,[1] but the Strait of Juan de Fuca appears to separate this coast into (1) a region of predominant glacial erosion and (2) a region where glacial deposition much exceeded the erosion of the ice. Puget Sound is this latter region to a unit.

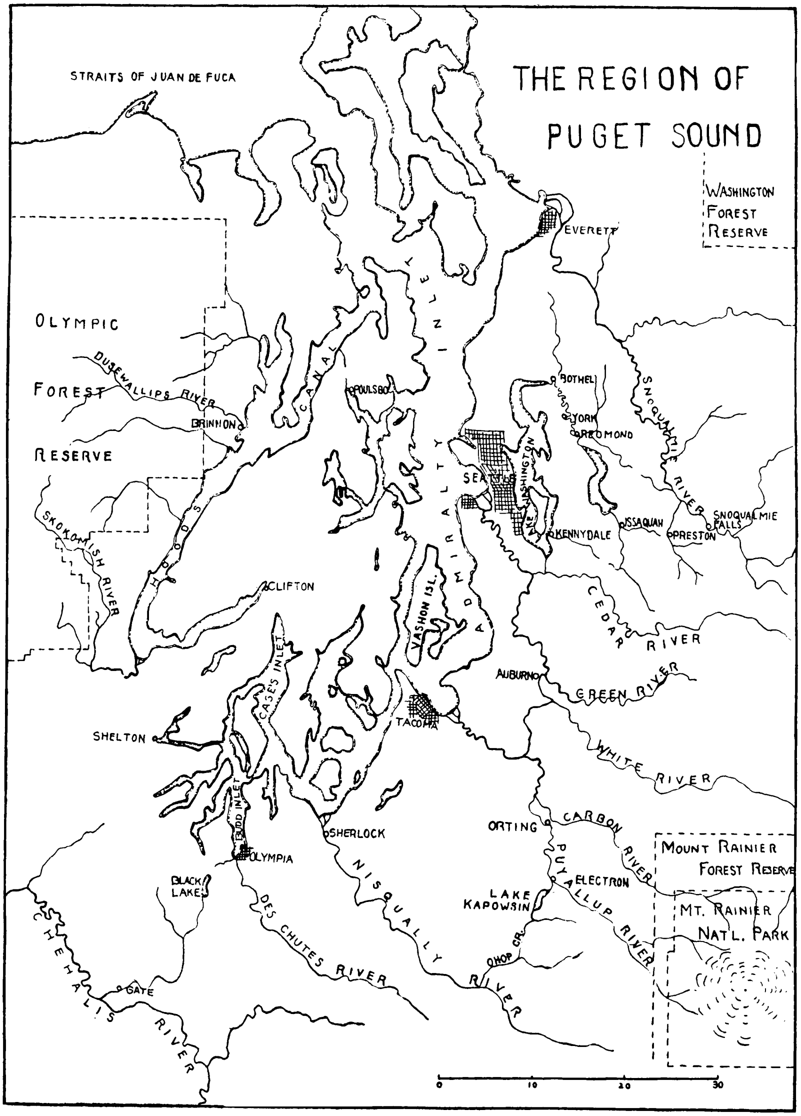
The complexly fingered arm of the sea known as Puget Sound lies in meridionally oriented troughs whose walls sometimes rise in sea cliffs 300 feet A.T. and whose maximum depths are approximately 1,000 feet below sea-level. To sea-level, at least, these fjord-like troughs are largely drift-walled. The larger stream valleys, lake valleys, and divides of the Puget Sound region are likewise fashioned in glacially transported material, and all share the roughly meridional orientation.

It is established that the ice of the last glaciation of Puget Sound was derived largely from snowfields to the north.[2] The axial lines of the grooved topography parallel the striae, and the ridges and valleys are at least veneered and often deeply covered by the youngest till of the region. The Vashon[3] ice which deposited that till sheet must have been related to the genesis of this peculiar and persistent topography in one of three ways: (1) the ice conformed closely to the ridges and grooves which were fashioned before its advent; (2) the last glaciation produced the present topography by erosion of an older and more nearly uniform drift surface; or (3) the Vashon

[1] G. K. Gilbert, "Glaciers and Glaciation," *Harriman Alaska Expedition.*

[2] Bailey Willis and G. O. Smith, "Tacoma Folio, No. 54," *U.S. Geological Survey.*

[3] Willis names the last glaciation of Puget Sound from Vashon Island, where its till is typically developed ("Tacoma Folio," *U.S. Geological Survey*).


THE REGION OF PUGET SOUND
STRAITS OF JUAN DE FUCA
WASHINGTON FOREST RESERVE
EVERETT
OLYMPIC FOREST RESERVE
DUSEWALLIPS RIVER
BRINNON
HOODS CANAL
ADMIRALTY INLET
POULSBO
BOTHELL
YORK
REDMOND
SNOQUALMIE RIVER
SEATTLE
LAKE WASHINGTON
KENNYDALE
ISSAQUAH
PRESTON
SNOQUALMIE FALLS
SKOKOMISH RIVER
CLIFTON
VASHON ISL.
CEDAR RIVER
AUBURN
GREEN RIVER
CASE'S INLET
TACOMA
SHELTON
WHITE RIVER
BUDD INLET
SHERLOCK
ORTING
CARBON RIVER
MOUNT RAINIER FOREST RESERVE
OLYMPIA
PUYALLUP RIVER
ELECTRON
BLACK LAKE
LAKE KAPOWSIN
MT. RAINIER NAT'L. PARK
DES CHUTES RIVER
NISQUALLY RIVER
OHOP CR.
GATE
CHEHALIS RIVER
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10
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invasion modified an older drift topography to that now existing. As to which of the explanations is correct, this paper is not concerned. For present purposes it is sufficient to show that, with ablation of the Vashon ice sheet, the topography essentially as it now is was exposed.

The depression occupied by Puget Sound is inclosed on the west by the Olympic Mountains, on the south by a low gravel plain between the Sound and the Chehalis River, and on the east by the Cascade Mountains. At the maximum of Vashon glaciation, the ice sheet filled the entire depression, extending south of Olympia at the most southern tip of Puget Sound. Outwash at this maximum stage is largely responsible for the extensive gravel plain constituting the Chehalis-Sound divide.

When retreat of the front of the Vashon ice sheet began and exposure of the depression of Puget Sound progressed northward, water accumulated at the ice front to a depth sufficient to escape across the gravel plain southward to the Chehalis River. The meridional orientation of hills and valleys exposed by ice retreat, together with the fact that the ridges were higher than the outwash plain across which drainage escaped, caused the ponded water to accumulate in long arms and inlets quite like those of the Sound today. Troughs without opening southward and closed by ice at the north would contain independent water-bodies whose levels were controlled by the lowest place in their basin rims. Troughs with openings lower than the Chehalis-Sound divide would become part of a complexly branched lake, whose level was controlled by the lowest altitude of that divide.

How far north did the retreating fingered ice front serve to hold up the increasing glacial waters to the discharge-way across to the Chehalis River? Postulating an uncrevassed ice sheet of sufficient thickness, the dam should have been effective during retreat throughout the entire length of the Sound. Denying this postulate, subglacial drainage of the lake seaward (northward) might have occurred early in ice retreat, in the manner described by Russell for lakes in the Malaspina Glacier at the foot of the Chaix Hills.[1] Investigation of the glacial features of Puget Sound has hardly gone far enough to justify definite conclusions on this question as yet. A brief description of the records of the principal glacial lakes of the region, as far as they have been studied, is given here, since such data alone can substantiate the preceding hypotheses and answer the question raised.

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[1] I. C. Russell, "Second Expedition to Mount Saint Elias," *Thirteenth Annual Report, U.S. Geological Survey*, Part II. Suggested by Willis in personal communication to writer.

GLACIAL LAKES OF HOOD'S CANAL

The form of this remarkable body of sea water is that of a great hook, the main portion of which is 50 miles in length and about two miles in its notably constant width. The broad valley of the Skokomish River joins the southern tip of the Canal from the west in much the same fashion that the arm which makes the hook form joins from the east. The topographic disposition of the trough of Hood's Canal and the two tributary valleys is perfectly adapted to the production of a lake of glacial water in front of the ice during its retreat. The inclosing drift bluffs at the head of the Canal are about 350 feet high, and from this altitude a gravel plain slopes gently south toward Shelton. Two or three channels across it are known in part, and probably represent escape of water from the earliest and highest ponding at the head of the Canal. This early lake was held to the level of about 350 feet in the main trough and up the two north-trending arms, while the ice retreated northward. The enlarging water-body reached the head of the northeastern arm before any important change of level occurred. Near Clifton a pass was exposed to Case's Inlet southward, lower than the gravel plain to Shelton, and, with exposure, it became the discharge-way of the glacial lake of Hood's Canal. The very distinct channel here is 60 feet deep, the col in it lying at about 220 feet A.T. The operation of the Clifton outlet determined a new lake level, and may thus define the second stage of the glacial lake of Hood's Canal. Discharge from both the first and second stages was into the larger lake held back of the Chehalis-Sound divide.

The bluffs of Hood's Canal, followed northward, continue everywhere sufficiently high to have held the glacial waters up to the Clifton outlet for almost the entire length of the Canal. The ridge and trough arrangement of the topography is interrupted in the broadest part of the peninsula between Hood's Canal and Admiralty

Inlet by a group of high hills of igneous rock. North of them the prevailing meridional orientation again occurs, and in the southern portion of one such trough, Dogfish (Liberty) Bay lies today. This till trough continues north across the peninsula to Hood's Canal with a swamp col near midlength 120 feet A.T. Here then was a pass lower than the Clifton outlet, and with its exposure the level of the ponded glacial waters fell and the Clifton channel was abandoned.

The Poulsbo channel, the outlet from Hood's Canal to Dogfish Bay, has valley sides that rise to an altitude of 200 feet above the col. A definite stream floor fragment lies on the east side of the summit, at about 150 feet A.T.

At the mouth of the Dusewallips River which enters Hood's Canal from the Olympics, occurs a portion of an ancient delta of that stream, the seaward front rising quite steeply from marine water to an even crest of 120 feet. It lies on the north side of the valley mouth, the form and extent being well shown in 20-foot contours on chart 6,450 of the U.S. Coast and Geodetic Survey. Save for one post-glacial ravine, no break occurs in the plane surface which reaches back at least two miles with an almost imperceptible slope upstream. The surface of the plain is everywhere of sand and stream-rolled gravel. Obviously this delta correlates with the 120-foot level of the Poulsbo channel. The significance of the 120-foot level and of the 150-foot terrace in the Poulsbo channel will be discussed later.

GLACIAL LAKE OF PUYALLUP VALLEY

One of the larger meridional troughs of the region lies parallel to Admiralty Inlet on the east. It is occupied in its northern extent by Lake Washington and, retaining its character of a till trough, reaches as far southward as Orting. Originally an arm of the Sound, post-glacial alluviation has silted it up. The most southern break in the valley walls is at Tacoma, and the topographic conditions south of this are such that a local glacial lake must have existed in the valley early in the final retreat. This portion of the trough is properly termed the Puyallup Valley.

The only known record of the Puyallup glacial lake is its outlet valley. In this valley lie Lake Kapowsin and Ohop Creek. A col just south of Lake Kapowsin causes a small stream entering there from the east to divide, one portion flowing north to the shallow linear lake and thence to the Puyallup River, the other reaching Ohop Creek and draining into the Nisqually River. The altitude of the col is 620 feet, above which the old valley bluffs rise 350 feet. It is probable that the deposits of this stream have raised the level of the Kapowsin outlet. The western margin of the Puyallup Valley northward toward Tacoma averages only 550 feet A.T. and Lake Puyallup must have early abandoned the Kapowsin outlet and found escape through spillways westward.

With discharge by either route, the waters of the lake were tributary to the larger lake held back of the Chehalis-Sound divide. When the ice dam failed to be effective, the Puyallup Valley became one of the group of flooded troughs constituting the major glacial lake of Puget Sound.

GLACIAL LAKES OF THE SAMMAMISH VALLEY

The Sammamish trough lies parallel to Lake Washington on the east. It has its inception ten miles north of Bothel and gradually deepens to its abrupt termination near Issaquah. The modern Lake Sammamish, seven miles long and 35 feet A.T., lies well to the south in the valley, a wooded swamp occupying the part north of the lake to Bothel and a creek draining the remaining length. The valley's southern portion is inclosed by three high rock hills, rising 1,500, 2,000, and about 2,500 feet A.T. Two low passes of preglacial origin cross the inter-hill areas. Beetling cliffs confine them in places.

East of Issaquah, altitude 90 feet, and on the northern flank of the largest of the three rock hills, is a considerable level area with an altitude of 425 feet. Coarse gravels and cobbles of glacial drift compose the surface, and are exposed in strata in several sections. Back from the margin of this deposit is a terrace 20 feet higher and with a still more extensive level surface continuing eastward. The face of the gravel deposit comprises the eastern wall of the Sammamish trough at Issaquah, and is dissected to a depth of about 300 feet by the stream which here enters from the east. Followed upstream, this creek is found, four miles out of Issaquah, to be wandering through a wide, flat-bottomed, swampy valley in which the stream appears incongruously small and ineffective. The valley floor here is about 50 feet higher than the gravel deposit with which it doubtless correlates.

At Preston, this old floor suddenly ends at 540 feet A.T., with the valley at full width. A descent of about 100 feet occurs to Raging River which comes in from the southeast and turns north at this point. But the level of the valley floor at Preston is continued, in the form of terraces, up the Raging River for four or five miles to the point where the grade of the stream has brought it up to the level of the Preston Valley.

At the time that Raging River was discharging into the Sammamish depression, it seems probable that an ice tongue occupied the trough, and held back the river to the level of the deposit referred to above. This deposit, hardly to be considered as a delta, is the oldest record of glacial waters in the Sammamish Valley.

A glacial lake of limited extent must have succeeded the ice tongue in the southern portion of Sammamish Valley, and discharged southward through the rock-walled valleys noted, both of which are floored with coarse, rounded gravel. The lowest altitude at which this lake could have existed with these discharge-ways is about 315 feet.

A channel exists across the till ridge between lakes Sammamish and Washington at the north base of Newcastle Hill, the lowest of the three rock hills noted. It is floored with coarse gravels. Another channel a mile north of the one just noted contains Phantom and Larsen lakes, and is floored with swamp deposits. Both are about 300 feet A.T., and must have existed contemporaneously or nearly so with the southward escape.

A third abandoned channel across the till ridge between the two parallel valleys exists near York, or Willows, a few miles north of Redmond. The summit of the York channel is 160 feet A.T. and no perceptible slope exists in the swampy bottom to the west. This fact argues a similar level of ponded water in the Lake Washington valley. Lake Washington's surface today is 130 feet lower than the col.

Correlating with the York channel is the highest level of the Redmond delta, a heavy gravel deposit which lies a mile east of the town of Redmond. This delta occurs at the debouchure of a former channel of Snoqualmie River into the Sammamish Valley. It is a gravel plateau, one square mile in area, rising abruptly, along its western and northern margins, from the lake valley bottom. Its summit profile is made up of four levels, 120, 130, 140, and 160 feet A.T. Excavations on the lakeward face show the entire height of about 70 feet to be composed of stream gravels, and in at least one case to have foreset bed structure. The terraced surface clearly records dissection of higher levels in the development of lower ones, and proves their development in a lowering water-body.

The relation of the highest level of the Redmond delta to the York channel has been noted. For the remaining levels, 140, 130, and 120 feet A.T., the present outlet past Bothel must have served. The valley here is one of the few till troughs of Vashon or earlier date, whose orientation is other than meridional. It must have presented so low an escapeway on its exposure that it cannot account for the three lower levels of the Redmond delta. Their explanation must be sought elsewhere, and will be discussed under the following heading.

GLACIAL LAKE OF PUGET SOUND—LAKE RUSSELL

It is now time to examine the records of the master lake of Puget Sound, whose level was determined by the Chehalis-Sound divide, and which in turn controlled the descending levels of several, if not all, of the minor lakes of the region.

This lake began its existence when the withdrawal of the Vashon ice sheet first exposed surfaces lower than the great gravel outwash plains between the Sound and the Chehalis Valley. Across these plains all escaping water from the Vashon glacier must have flowed as long as the ice remained a dam at the north. As already noted, there is the possibility of escape of drainage northward through englacial or subglacial tunnels at a level lower than the Chehalis-Sound divide, before the clearing of the northern portion of the Sound occurred. The northern limit of this great lake thus is at present quite indefinite.

The outlet for all water escaping southward from fresh-water bodies in Puget Sound lies southwest of Olympia, through the col between the Sound and the Chehalis River, with an elevation of 120 feet A.T.

A swamp at the col drains both north and south. Within two miles of Puget Sound drainage from this swamp flows south to the Chehalis River and thence to the Pacific Ocean, 50 miles distant.

The narrowest place in the channel of the glacial stream which discharged over the divide is close to its inception, about 1½ miles from Budd's Inlet. Here the width of the 120-foot channel is less than one-fourth of a mile. This is cut in the bed of a considerably wider channel, whose floor is 160 feet A.T. A definite terrace occurs here, and also in the swamp a mile distant at 140 feet. These three levels are seen repeatedly in the 17 miles of channel length, though their altitude descends and their distinctness is less marked farther south. The ancient outlet today contains Percival Creek north of the col, and Black Lake and Black River south of it.

At Gate, the Black Lake outlet channel joins the wide Chehalis Valley. At the debouchure occurs a considerable area of gravel spreading out into the larger valley from the north. The deposit presents a rather abrupt face down the valley. Its surface altitude is approximately 100 feet above sea-level. Farther down the Chehalis Valley, glacial gravels occur only at the mouths of tributary valleys from the north, none being found in a careful search for five miles immediately below Gate.

The genesis of the Gate gravels is evidently associated with the operation of the Black Lake outlet and their deposit here suggests slack water in the Chehalis Valley, standing at an altitude at Gate of about 100 feet.

The suggestion of standing water at Gate and in the Chehalis Valley, much beyond the limits of glaciation, and so topographically placed that ice could not close it if it were glaciated, turns one to a consideration of the sea-level at the time of Vashon glaciation and retreat.

In the study of the physiography of Puget Sound, various shell-bearing terrace fragments have been observed. Willis notes the occurrence of the lowest, 15–20 feet above present mean tide,[1] and Arnold has recorded one 40 feet above sea-level on the west side of the Olympic Mountains.[2] Terraces at both of these levels have

[1] Bailey Willis and G. O. Smith, *op. cit.*

[2] Ralph Arnold, "Geological Reconnaissance of the Olympic Peninsula," *Bull. Geol. Soc. Am.*, XVII.

been repeatedly observed by the writer, occurring on all important inlets of the Sound. Shell-bearing terraces at higher levels, though rarer, have been found at about 60 and 80 feet, and in three places 100 feet above present tide.

Of the marine shell-bearing terraces at the highest level, two are on the west side of Hood's Canal, and one at Tumwater on Budd's Inlet. On one of the Hood's Canal 100-foot terraces, the sod and forest soil are literally a mass of comminuted shell fragments to the depth of a few inches. The 80-foot terrace is present immediately below it.

Unless error has been made in these observations, there is here conclusive evidence that at some time subsequent to the fresh-water occupancy of Puget Sound's southern valleys, the land was 100 feet lower than now.

From the rare occurrence of the consecutively higher marine terraces of Puget Sound, and from the lack of any evidence to the contrary, it has been assumed that the series represents successive stages in a rising of the land which has been in progress throughout post-glacial time. On this supposition, the 100-foot terrace represents the level of sea water on first entrance into the Sound after the ice retreat from its northern portion. The 100-foot gravels at Gate and the 100-foot marine terraces of the Sound seem good evidence that the entire region was that much lower when the greater lake of Puget Sound discharged southward across the Chehalis-Sound divide during the retreat of the Vashon ice sheet. This lake then was but 20 feet above the sea at its lowest stage.

It is well established by the outlet channel that static water was held to its levels in the southern part of the Sound by ice in Admiralty Inlet during Vashon retreat. The limited amount of examination thus far possible has shown four rivers of the region to possess deltas at one or more levels between 120 feet and 160 feet A.T. The Des Chutes River has an old delta plain in the southern part of Olympia 160 to 170 feet high, and the Nisqually River dissects an old delta at Sherlock, three miles back from the present coast, the summit plain of which is about 160 feet high. Both deltas correlate with the 160-foot terrace in the outlet near Black Lake. They have been examined only cursorily thus far, and nothing is known concerninng lower stages.

Farther north occur the Redmond and Brinnon deltas, the former with correlating terraces for the three stages of the lake indicated by the outlet, the latter with but the lowest stage recorded. Associated with these deltas are respectively the York and Bothel, and the Poulsbo channels at appropriate altitudes, and each leading into a valley open through to the Black Lake outlet at the south.

Though the evidence of the two northern deltas may,perhaps be of insufficient weight to establish the extent of the master lake as far north in the Sound as the Bothel and Poulsbo channels, yet it is quite suggestive of such extension. The levels must otherwise be explained as a coincidence of local ponding, and the greater lake must in such case be considered as having lowered from the Black Lake outlet earlier in the ice retreat, by tunnel drainage northward.

It is of much interest to note that there is nothing in any collected data concerning the various glacial lakes or the terraces of early marine occupancy which suggests tilting or warping of the region in the uplift which has taken place.

It seems fitting that to this lake of Puget Sound, with outlet southward through Black Lake channel and with levels controlled by that channel, a name should be given in tribute to the work of a geologist to whom our knowledge of the physiography of western North America must always be deeply indebted. In memory of Israel Cook Russell may this water body be known as *Lake Russell.*

In an article by Upham in the *American Geologist*,[1] the Black Lake outlet is noted and the suggestion made that a glacial lake probably existed in Puget Sound and discharged through the channel. Upham supposed the col to be 170 feet high. This article was not seen until the work on which the present article is based was all but completed, the outlet region having already been examined three times. Though having no influence on this work, it is hereby acknowledged as the first published notice of the existence of Lake Russell.

The writer is indebted to Mr. Bailey Willis for careful examination and criticism of the data presented herewith, and for valuable suggestions which have given broader conceptions and have modified conclusions in this paper.

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[1] Warren Upham, "Glacial and Modified Drift in Seattle, Tacoma, and Olympia," *American Geologist*, XXIV, No. 4.